Paper L 7

CHANGE IN LAND USE IN THE PHOENIX (1:250,000) QUADRANGLE, ARIZONA BETWEEN 1970 AND 1973: ERTS AS AN AID IN A NATIONWIDE PROGRAM FOR MAPPING GENERAL LAND USE

John L. Place, *U.S. Geological Survey, Geographic Applications Program, Washington, D.C.*

ABSTRACT

Changes in land use between 1970 and 1973 in the Phoenix (1:250,000 scale) Quadrangle in Arizona have been mapped using only the images from ERTS-1, tending to verify the utility of a standard land use classification system proposed for use with ERTS images. ERTS 9 x 9 transparencies, interpreted by several techniques, were used to update a land use map previously compiled with 1970 air photos. Types of changes detected have been (1) new residential development of former cropland and rangeland; (2) new cropland from the desert; and (3) new reservoir fill-up. The seasonal changing of vegetation patterns in ERTS has complemented air photos in delimiting the boundaries of some land use types. Inasmuch as air photos normally are a year or more out of date, ERTS provided currency.

ERTS images, in combination with other sources of information, can assist in mapping the generalized land use of the fifty states by the standard 1:250,000 quadrangles. Several states are already working cooperatively in this type of mapping. This monitoring of land use change can be of value to planners and resource managers at Federal, state, and regional levels, both for resource development and environmental protection in broad areas of the United States. The ERTS images focus attention on those areas requiring more intensive study.

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The objectives of ERTS investigation number SR 186 have been (1) to test the interpretability of ERTS-1 images for use in the mapping of generalized land use, and (2) to test the applicability of ERTS-1 images in detecting changes and updating maps.

After using the ERTS images, it is apparent that they will be of help, in combination with other sources of information, in mapping the generalized land use of the fifty states by 1:250,000 quadrangles. A cooperative program has already been established to do this with several states and multi-state regional commissions. The ERTS coverage could be of particular value in selecting which quadrangles are in greatest need of update in the first cycle of revision.

Figure 1 is the most recent map showing land use for most or all of the United States. It presents information that was collected by conventional means over a period of several years, and it was in part out of date at the time that it was published by the USGS in the National Atlas of the United States. With the advent of earth satellite sensors, supplemented by air photos, it became possible to monitor land use changes on a nearly real-time basis. It was believed that to reduce costs, the mapping and updating should be computerized and should be built around the standard 1:250,000-scale topographic quadrangles, the largest scale of maps for which we have complete coverage of the fifty states.

The Phoenix quadrangle in Arizona (see Figure 2) was selected as the pilot project, and it would also serve as a test of land use mapping in arid lands. Figure 2 shows a 2 x 2 matrix of four quadrangles in southern Arizona. The Phoenix quadrangle is the one to the northwest. The other three were investigated under sponsorship of the EROS Program as a complementary effort.

The first step in producing a computerized map of land use is to compile by hand, as shown in Figure 3, while interpreting high-altitude air photos, supplemented by satellite imagery. This particular hand-compiled map of land use in the Phoenix Quadrangle was drawn from U-2 photos taken in November 1970.

The data from the land use maps were read into a computerized data bank along with data on land ownership, soils, drainage, and census codes for state, county and tracts as listed in Figure 4.

Figure 5 illustrates the first example of an automated plot of land use from the computer data bank. The general land uses are shown in color. The black plate from the standard topographic quadrangle has been overlain to provide place names, linear patterns and much of the marginal information.

Figure 6 shows a blow-up of the eastern edge of that last map, showing most of the Phoenix metropolitan area. The colors represent the first level of our land use classification system, and different symbols are used to show the second level of detail.

Figure 7 presents the land use classification system which was used in the Arizona study. It has been published in USGS Circular 671. The first level was designed for interpreting satellite imagery; the second level for high-altitude aircraft photography. It is open ended for users to add other levels as desired.

An example of one color plate of the land use map is presented in Figure 8. Our Calcomp 763 plotter plotted this cropland plate. The dense symbols are tree crops, in this case citrus, and the lighter patterns are other crops. Changes in the land use record can be made very simply by card input to update specific cells.

Change detection has been an important part of our work, with special emphasis on our ERTS experiment. Of the many techniques that we have used to interpret ERTS images, the one that worked best was the seasonal comparison of ERTS color composites.

Figure 9 is a color composite of the Phoenix area in August 1972, right after the launch of ERTS-1. Our processing got better later, but desert vegetation looks drab, colorless during the summer. The irrigated fields near Phoenix show red. Here the MSS 4, 5, and 6 bands are combined.

An October view of the same area is shown in Figure 10. Improved color results from the substitution of the 7 band in place of the 6 band in the composite. However, the natural vegetation still looks dry and colorless before the beginning of the primary rainy season.

Figure 11 is a February ERTS scene during a very rainy winter. The natural grasses in the desert show bright red, and desert brush appears redder and lusher. These are bands 4, 5, and 7.

Figure 12 is the May ERTS scene of the same area. The natural grasses are beginning to brown out. The pattern of Phoenix urban land use is particularly clear in this ERTS composite. The upper end of the new Painted Rock Reservoir is visible near the southwest corner. Study of reservoir fluctuation may be one use of ERTS.

Figure 13 is a September ERTS scene from the pass west of the one shown in the previous three figures. In September, the Painted Rock Reservoir downstream form Gila Bend has not yet started to fill. The fall vegetation is too drab to silouette man-made features well; however, the mine tailings and pits at Ajo show up clearly.

An I^2S Color Additive Viewer was used to create experimental color composites. This viewer handles 70 mm film chips. As illustrated in Figure 14, to get greater magnification, 70 mm chips were cut out of 9 x 9 transparencies, and these were mounted in the film viewer.

Figure 15 illustrated what the chip looks like when blown up onto the display screen of the I^2S viewer. At a scale of 1:380,000 on the scope, it resembled the 1:250,000 scale of the 1970 hand-drawn map that we were trying to update.

When that MSS 5 band was combined with bands 4 and 6 in the viewer, the color composite shown in Figure 16 was created. This is a photograph of the display scope, one way to keep a record of experimental settings.

When ERTS images from different time periods were overlain using different color filters, it was expected that differences of changes would be enhanced. They were as shown in Figure 17, but primarily it enhanced differences in stage of vegetation growth, not differences in general land use. This technique was a little disappointing. Quick-flip technique also showed too much clutter.

We also tried density slicing of an ERTS 5 band image using a Data Color Viewer as shown in Figure 18. This gave us experience in planning for the use of computer compatible tapes which are now being investigated. We learned to focus in on areas of relatively homogenous use, that is, urban or rural, but not both. In Figure 18, by focussing-in on downtown Phoenix, business streets and commercial-industrial districts are enhanced, but it is still cluttered.

From all these image interpretation techniques, particularly the color composites of the ERTS images, we compiled maps of change detected using ERTS. Early efforts had many inaccuracies, but as seasonal changes in vegetation were monitored by ERTS, a much more accurate delineation was possible. The muted colors shown in Figure 19 are the original 1970 land use map. The brighter colors are the changes detected using only ERTS images. The red is new urban, the green is new cropland, and the dark blue is new water surfaces, as shown in the legend in Figure 20.

As a check of accuracy, we did the same change detection shown in Figure 21, using U-2 air photographs taken November 1972. This map of change is more detailed than the ERTS change map, but the ERTS map is more up-to-date reflecting changes of the past few months. The total areas of change are similar in the two maps, and the distribution pattern is also similar. ERTS and air photos complement each other. ERTS certainly focusses attention on rapidly-changing areas.

In Figure 22, the total change in the Phoenix quadrangle has been summarized from data bank in this matrix of change "from" and "to".

The utility of having other factors combined in the data bank is illustrated in Figure 23 where that last change matrix is divided up in four matrices by land ownership classes, private, state, public lands, and Indian lands.

As examples of queries that we have made to the Phoenix data bank, we asked, how much land has been lost from agriculture to urban use in Maricopa County between February and November 1970? The answer: 6 square kilometers. Of the best agricultural soil, how many square kilometers are still in rangeland? The answer: 1760 square kilometers. Used for urban? 349 square kilometers. And these areas could be plotted as maps.

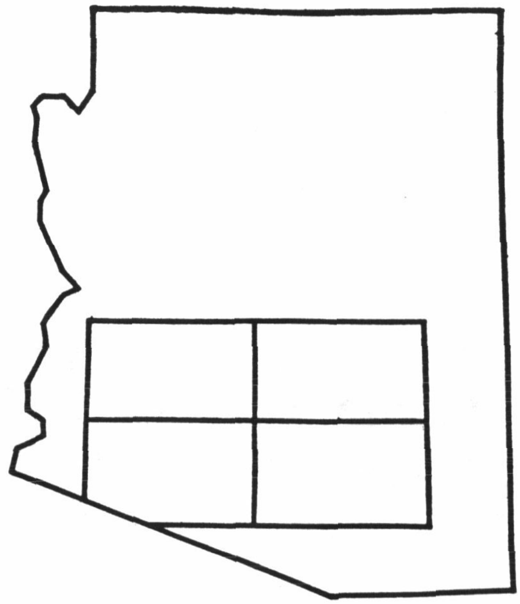
In the past few weeks, more effort has been given toward plotting the original digitized polygons in map form, thus gaining greater accuracy over the cellular maps. In Figure 24, the land use patterns on the east side of Phoenix are outlined as polygons by a Calcomp 763 plotter.

In Figure 25, land use polygons are filled-in automatically with colored symbols. In this case, the area is around Gila Bend, Arizona.

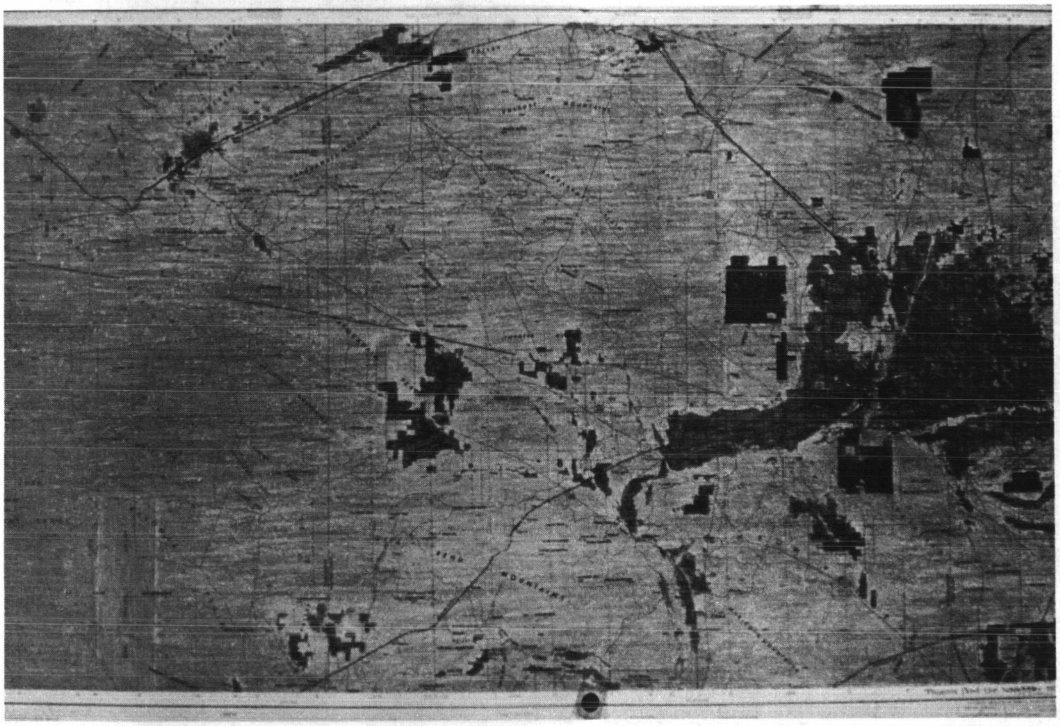
We have the capability to convert the polygons automatically to cells in order to exploit our existing soft-ware for statistical analysis.

Primarily we have been creating an array of procedures to be applied to various tasks. The USGS has been attempting to work with individual states, mostly through multi-state regional organizations and have established cooperative working arrangements with the Ozark Regional Commission and the Appalachian Regional Commission to map parts of their regions, using the procedures that I have just described, developed originally for the Phoenix Quadrangle, utilizing all available sources of information, including ERTS images. The ERTS images provide currency and improved interpretation of land use where seasonally-changing patterns help to indicate use.

1. The land use map from the National Atlas of the United States. This is the most recent map of land use covering all or most of the country, but it took several years to compile and is many years out of date.



2. An orientation map of the four 1:250,000 scale quadrangles currently being worked on in Arizona. The Phoenix quadrangles is the one on the northwest.



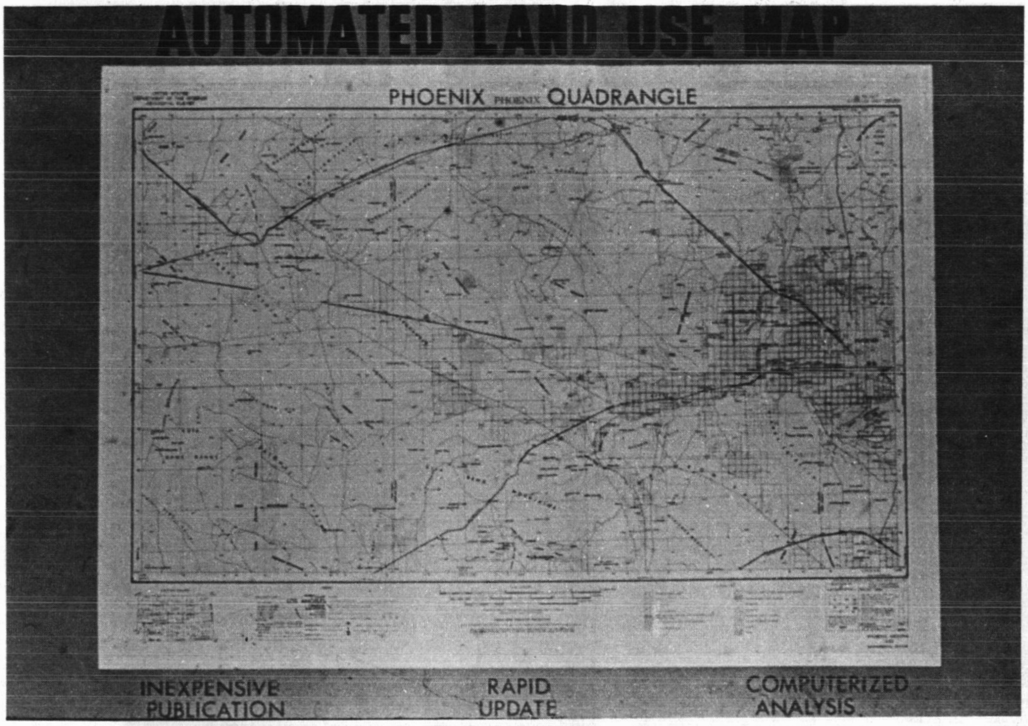
3. Hand-drawn land use map of the entire Phoenix Quadrangle (scale 1:250,000), compiled from aerial and satellite photography. The ERTS images were compared to this type of map in order to detect changes. This map is merely an interim working step in digitizing the computerized model and map.

FACTORS IN DATA BANKS

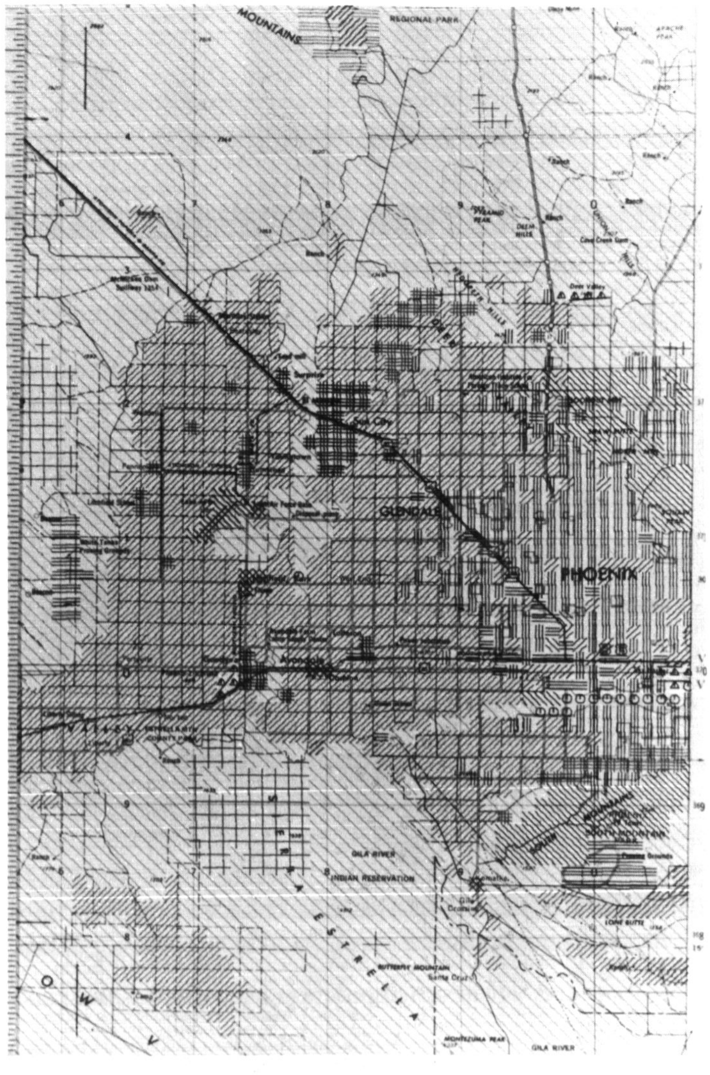
LAND USE	DRAINAGE
OWNERSHIP	STATE CODE
SOILS	COUNTY

TRACT

4. A list of the factors recorded in the computer data bank for the Phoenix Quadrangle. The date of the land use information is also recorded.



5. Land use map of the entire Phoenix (1:250,000) Quadrangle plotted automatically from the computerized data bank and overlain with the black plate from the standard topographic sheet. This data bank and map represents land use in 1970; it will be updated through use of ERTS images.



6. Land use map plotted automatically from a computer data bank of the Phoenix Quadrangle. This shows the City of Phoenix on the eastern edge of the map. The changes detected in the ERTS images will be used to update this data bank.

LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

LEVEL I CATEGORIES
LEVEL II CATEGORIES

01 URBAN AND BUILT-UP

01 RESIDENTIAL
02 COMMERCIAL & SERVICES
03 INDUSTRIAL
04 EXTRACTIVE
05 MAJOR TRANSPORT ROUTES & AREAS
06 INSTITUTIONAL
07 STRIP & CLUSTERED SETTLEMENT
08 MIXED
09 OPEN & OTHER

02 AGRICULTURAL

01 CROPLAND & PASTURE
02 ORCHARDS, GROVES, BUSH FRUITS, VINEYARDS & HORTICULTURAL AREAS
03 FEEDING OPERATIONS
04 OTHER

03 RANGELAND

01 GRASS
02 SAVANNAS (PALMETTO PRAIRIES)
03 CHAPARRAL
04 DESERT SHRUB

04 FORESTLAND

01 DECIDUOUS
02 EVERGREEN (CONIFEROUS & OTHER)
03 MIXED

LEVEL I CATEGORIES
LEVEL II CATEGORIES

05 WATER

01 STREAMS & WATERWAYS
02 LAKES
03 RESERVOIRS
04 BAYS & ESTUARIES
05 OTHER

06 NON-FORESTED WETLAND

01 VEGETATED
02 BARE

07 BARREN LAND

01 SALT FLATS
02 SAND (OTHER THAN BEACHES)
03 BARE EXPOSED ROCK
04 BEACHES
05 OTHER

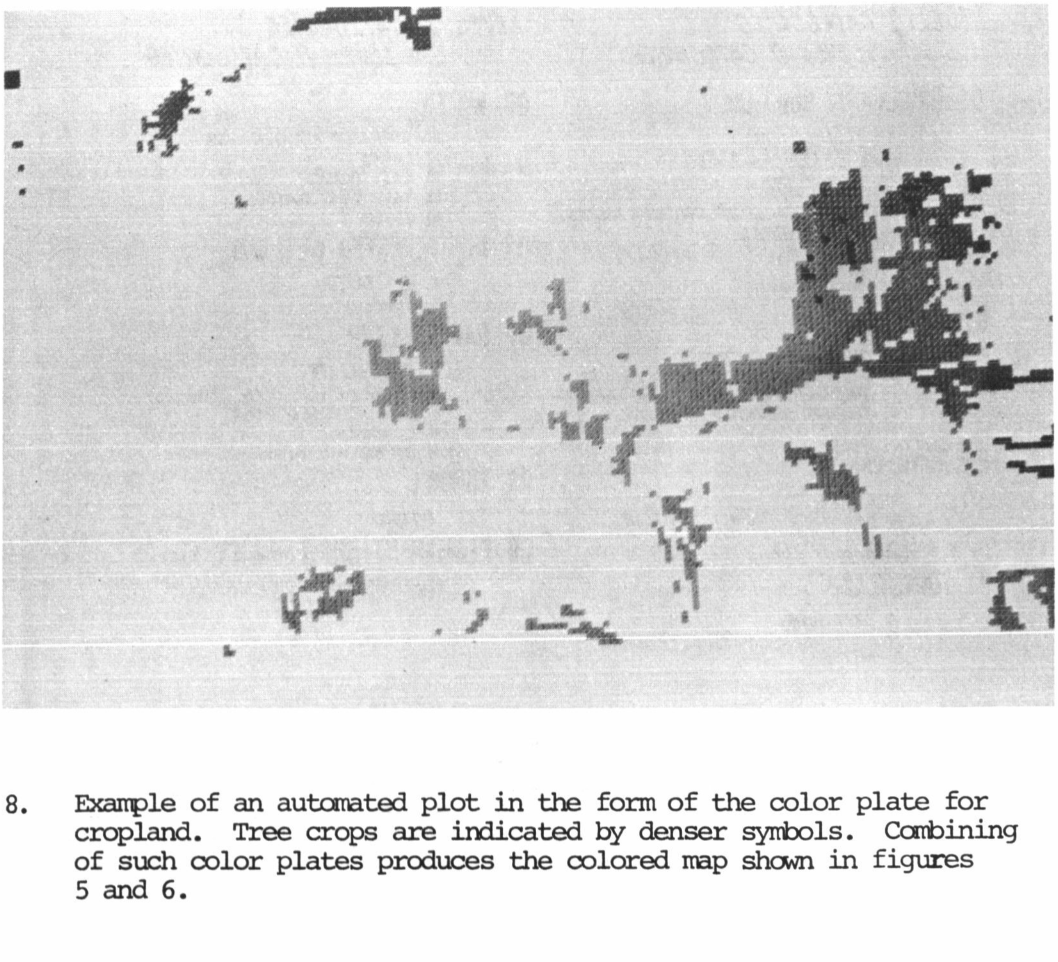
08 TUNDRA

01 TUNDRA

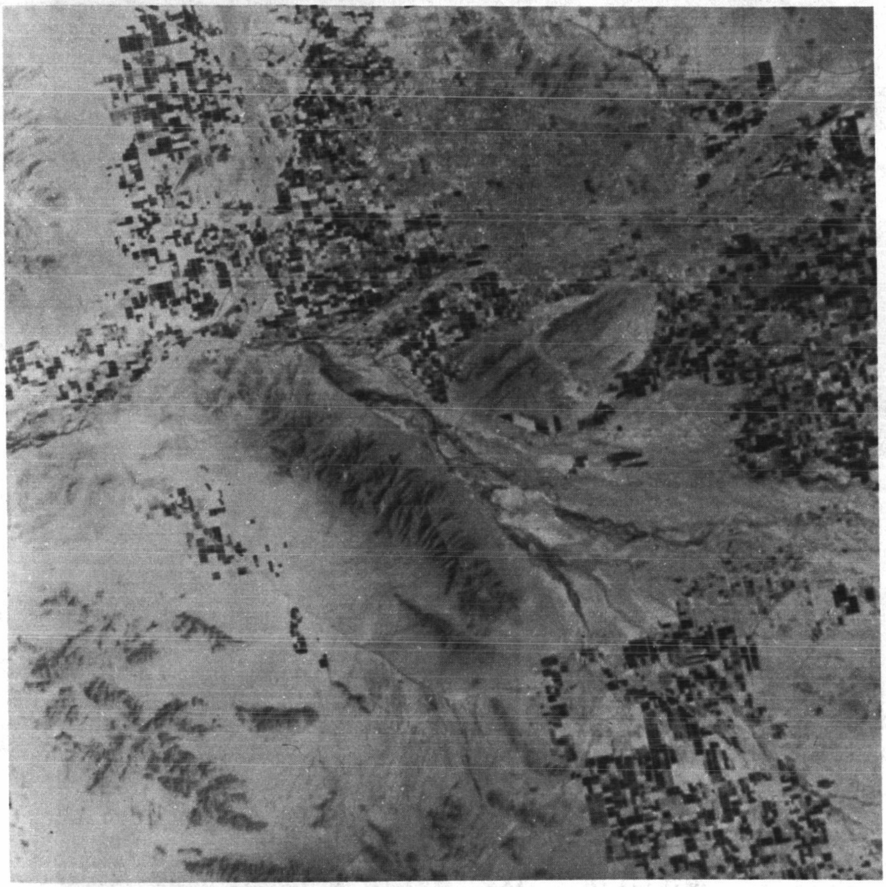
09 PERMANENT SNOW AND ICE FIELDS

01 PERMANENT SNOW & ICE FIELDS

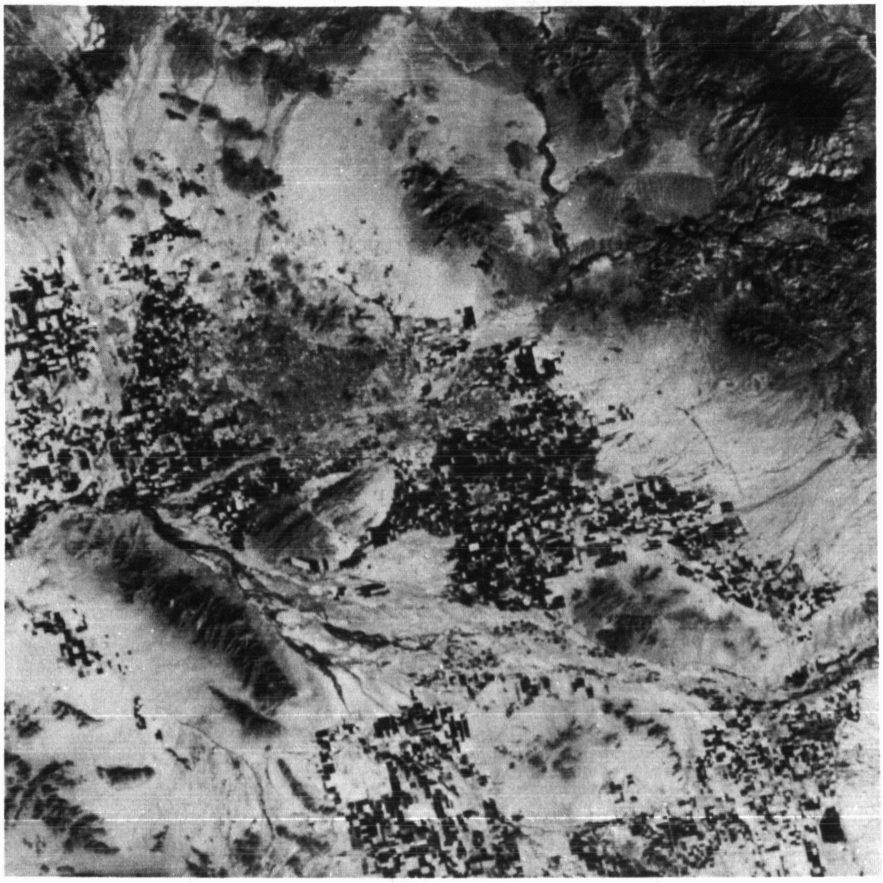
7. The land use classification system designed for use with ERTS images (Level I) and with high altitude NASA aerial photographs (Level II). It was found that some of the Level II categoreis could be distinguished from ERTS images most of the time. The classification system is being used with the Phoenix Quadrangle project.



8. Example of an automated plot in the form of the color plate for cropland. Tree crops are indicated by denser symbols. Combining of such color plates produces the colored map shown in figures 5 and 6.

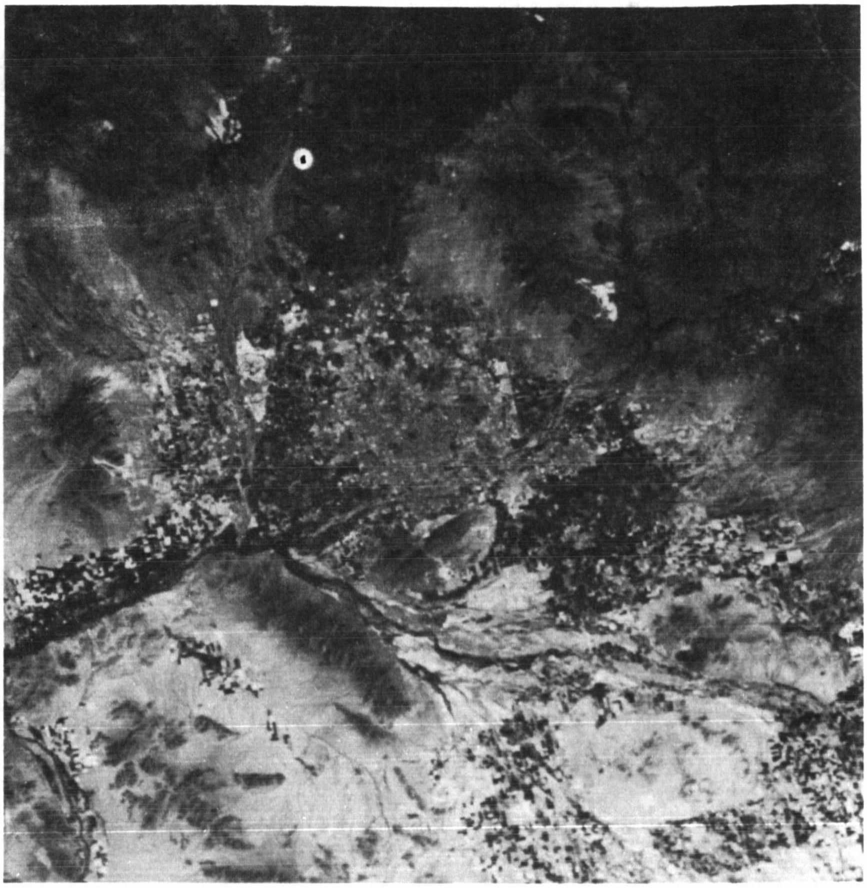


9. Print of ERTS color composite with an approximate scale of 1:1,000,000. This shows Phoenix and vicinity on August 23, 1972. This was one of the first ERTS frames and the processing was not as good as it became later. Nevertheless, the dryness, i.e., absence of red tones, can be seen as the desert vegetation has withered during the summer dry season. Mines appear as blue scars. Color composite was made with bands 4, 5, and 6.

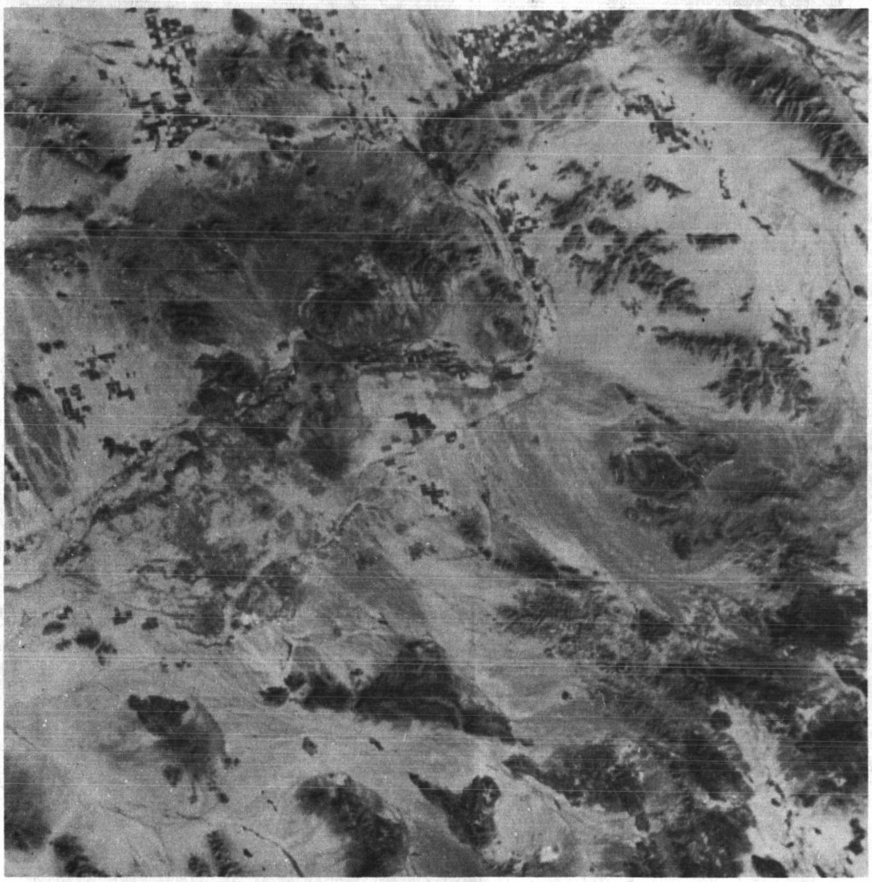


10. Print of an ERTS color composite with an approximate scale of 1:1,000,000. This shows Phoenix and vicinity on October 16, 1972. The desert shrubs are dry and colorless at the end of the dry season. Many fields are fallow along the edge of the desert. Only by comparing crop patterns for all seasons can we accurately delineate the land use boundaries. Color composite was made with bands 4, 5, and 7.

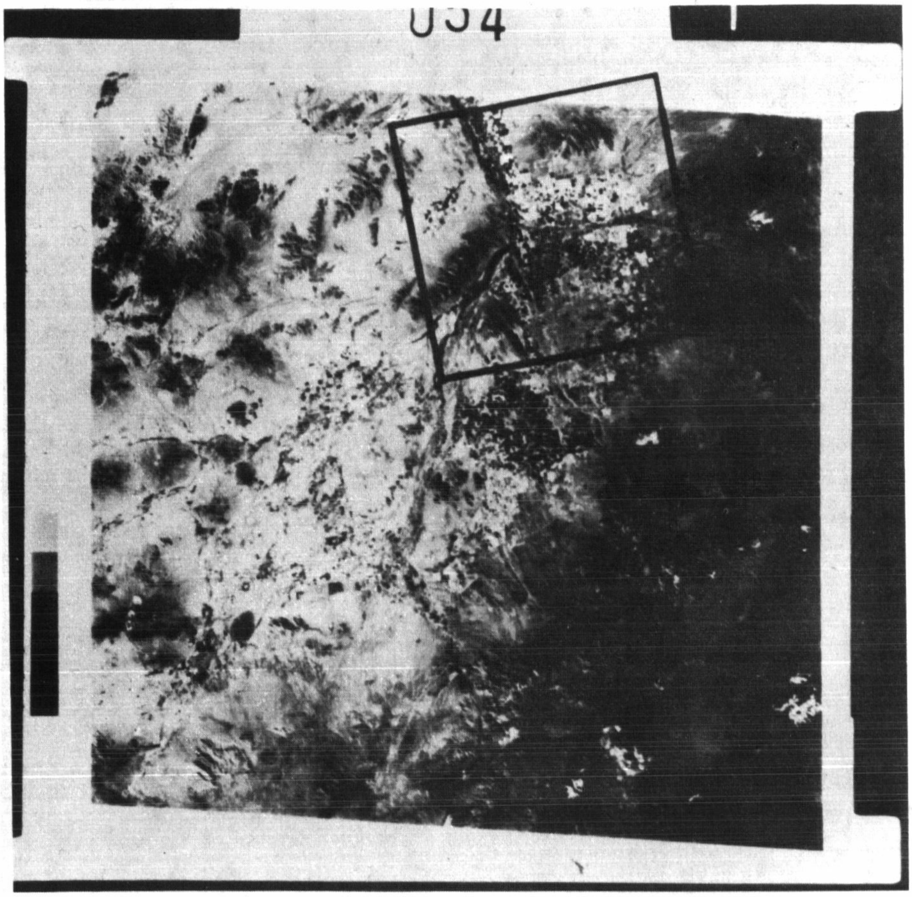
11. Print of an ERTS color composite with an approximate scale of 1:1,000,000. This shows Phoenix and vicinity on February 19, 1973. This shows lush desert grasses present during a particularly wet rainy season. Note that the irrigated crops are not redder than in the images from other seasons. Color composite was made with bands 4, 5, and 7.



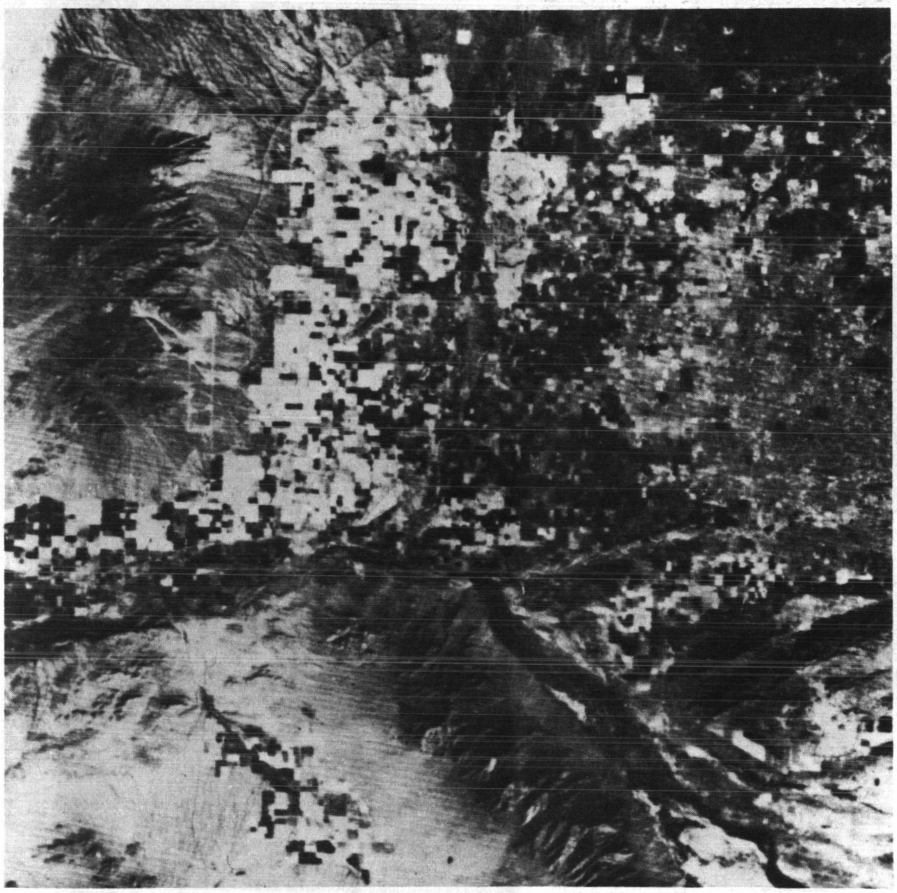
12. Print of an ERTS color composite with approximate scale of 1:1,000,000. This shows Phoenix and vicinity on May 2, 1973. The urban patterns within Phoenix show up as blue line commercial streets. With ten times magnification, the textures of industrial districts and the central business district are discernable. The residential areas are purplish pink. The Painted Rock Reservoir is full of water for the first time. Its upper end is visible on the west edge of the image. Salt River also has surface water, revealing channel locations, a rare sight. Color composite was made with bands 4, 5, and 7.



13. Print of an ERTS color composite with approximate scale of 1:1,000,000. This shows much of the Phoenix Quadrangle southwest, of Phoenix on November 4, 1972. Notably it showed the Painted Rock Reservoir before it was allowed to fill. The May 1973 image shows the upper end of that reservoir full of water. Note the open pit copper mines showing clearly at Ajo in the lower right of the image. Color composite was made with bands 4, 5, and 7.



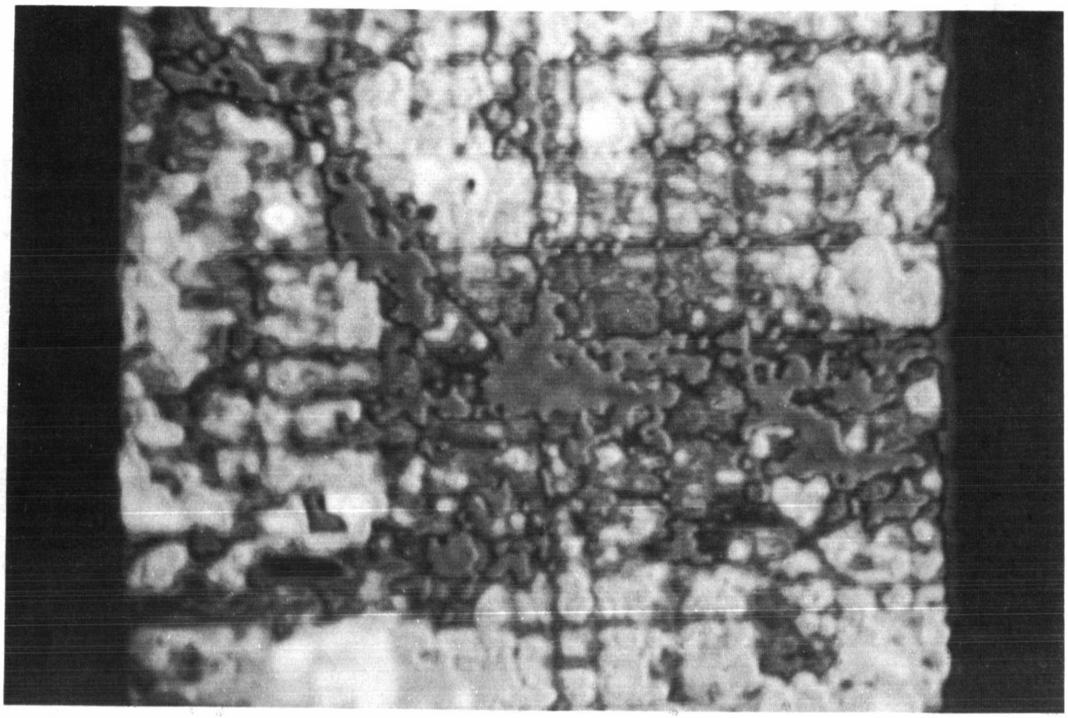
14. Example of how a 70 mm chip is cut out of a 9 x 9 transparency showing south-central Arizona. The 70 mm chip is to be used in an I^2S Color Additive Viewer where it will be magnified from 1:1,000,000 to a scale of about 1:380,000 on the display scope of the viewer. This scale approximates the base mapping scale of 1:250,000 used in the Phoenix Quadrangle Project.



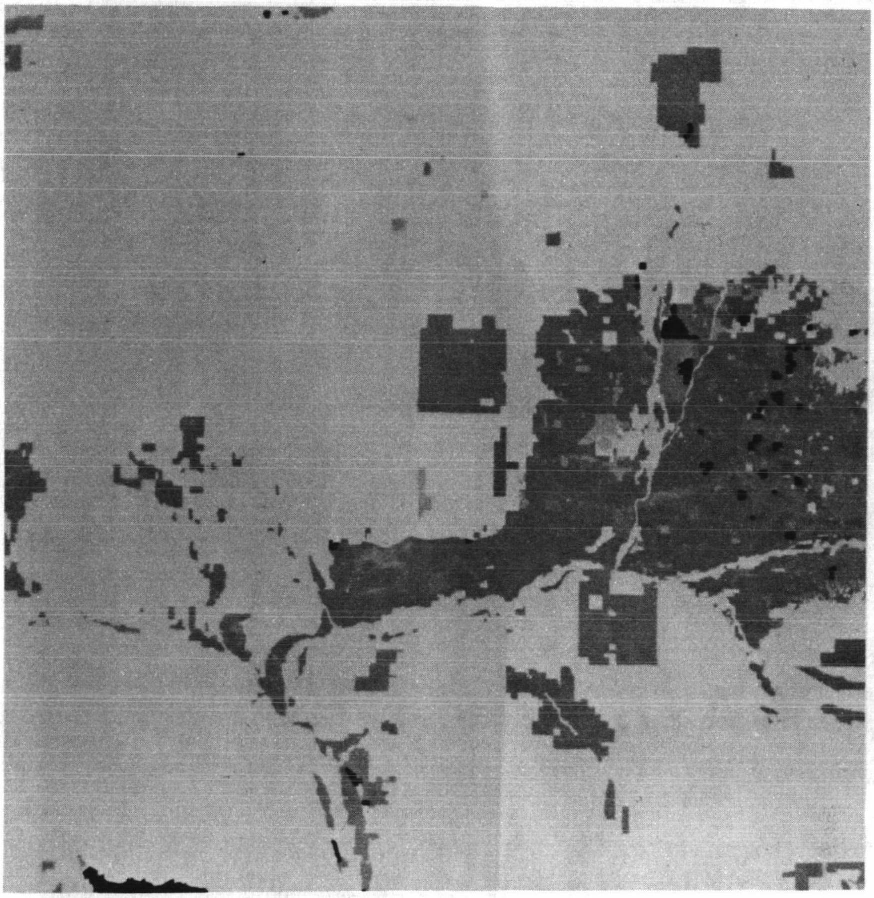
15. Examples of a three-times magnification of the 70 mm chip shown in the previous illustration. This approximates its scale on the display screen of the I^2S viewer, however, in the viewer it would be combined into a color composite with identical chips from other bands. This is a band 5 image of the Phoenix area.

16. Example of a color photograph taken of the display screen of the I^2S Color Additive Viewer. This one is the ERTS color composite (bands 4, 5, and 6) of the west side of Phoenix taken in November 1972. Scale approximately 1:300,000.

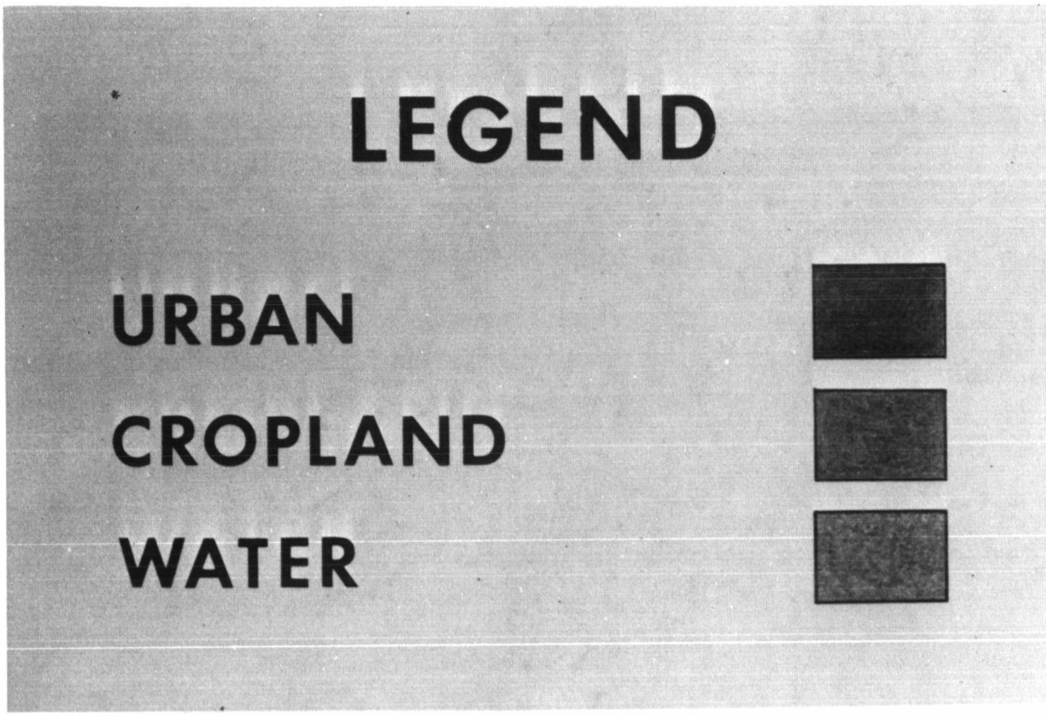
17. An attempt at change detection by using ERTS images two month's apart with different color filters. Different satellite positions causes some blurring and clutter. In general, unchanged areas cancel out as brown. Yellow or blue colored areas indicate possible change, but most is due to different stages of the agricultural cycles, <u>not</u> change in land use. These were band 5 images taken west of Phoenix in August and October 1972. A one year change will be tested.



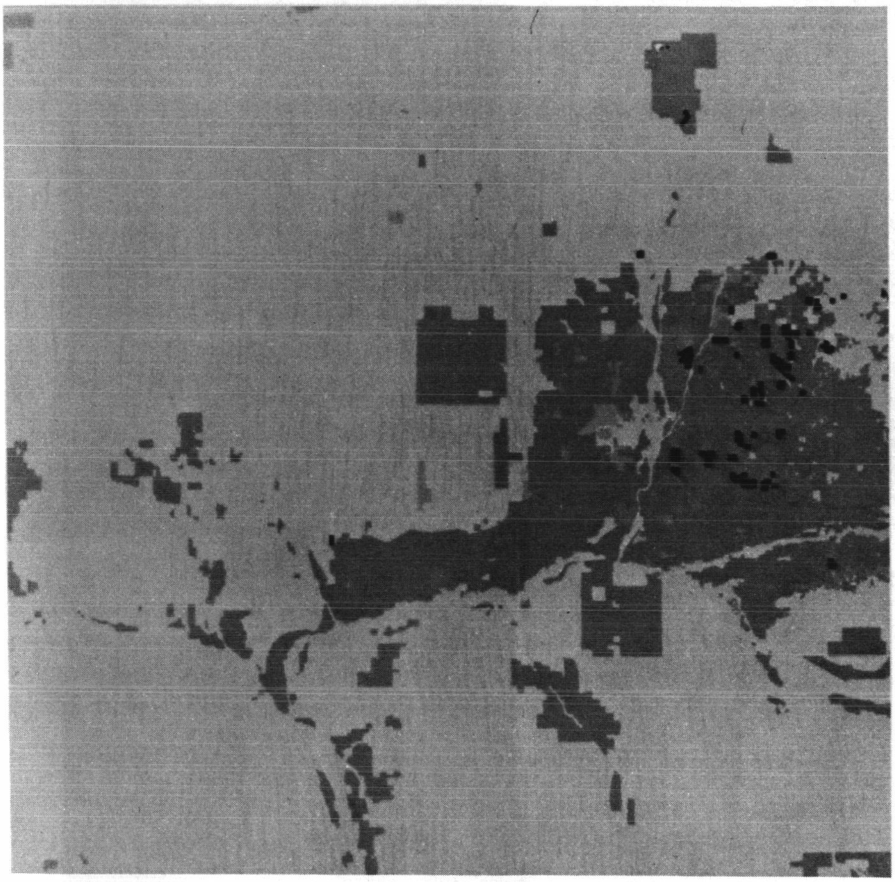
18. Using the Data Color Viewer to focus in on central Phoenix and to slice gray-scale densities, non-vegetated commercial and industrial districts appear dark blue, business streets red, and residential areas pale blue and green. An ERTS band 6 was used.



19. Change in land use detected using only ERTS images obtained throughout the period August 1972 and May 1973. The area shown is the eastern half of the Phoenix Quadrangle. It is important that total areas of urban growth detected by aerial photography or by satellite sensing are similar and the location of the primary clusters are essentially the same. New areas of change since the date of the aerial photos show how the two collection systems complement each other.



20. Legend for the maps of land use change, figures 19 and 21.



21. Change in land use detected using ERTS-underflight aerial photography taken in November 1972 in the vicinity of Phoenix. The southernmost 10% of the Phoenix Quadrangle was never covered by the aerial photography. The red change is new residential, the green is cropland, and the blue is surface water.

CHANGE OF LAND USE IN THE PHOENIX QUADRANGLE AS DETECTED FROM ERTS

NOVEMBER 1970 TO MAY 1973

(SQUARE KILOMETER CELLS)

FROM \ TO	RESIDENTIAL	CROPLAND	DESERT SHRUB	RESERVOIR
RESIDENTIAL	-	0	0	0
CROPLAND	30	-	0	19
DESERT SHRUB	3	23	-	55
RESERVOIR	0	0	0	-

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22. Matrix of change found in the Phoenix Quadrangle between 1970 and 1973. Areas are in square kilometers.

CHANGE OF LAND USE BY LAND OWNERSHIP TYPE IN THE PHOENIX QUADRANGLE AS DETECTED FROM ERTS

NOVEMBER 1970 TO MAY 1973

(SQUARE KILOMETER CELLS)

PRIVATE

FROM \ TO	RESIDENTIAL	CROPLAND	DESERT SHRUB	RESERVOIR
RESIDENTIAL	-	0	0	0
CROPLAND	30	-	0	17
DESERT SHRUB	1	3	-	39
RESERVOIR	0	0	0	-

STATE

FROM \ TO	RESIDENTIAL	CROPLAND	DESERT SHRUB	RESERVOIR
RESIDENTIAL	-	0	0	0
CROPLAND	0	-	0	1
DESERT SHRUB	0	5	-	3
RESERVOIR	0	0	0	-

FEDERAL PUBLIC LAND

FROM \ TO	RESIDENTIAL	CROPLAND	DESERT SHRUB	RESERVOIR
RESIDENTIAL	-	0	0	0
CROPLAND	0	-	0	0
DESERT SHRUB	2	15	-	9
RESERVOIR	0	0	0	-

INDIAN LAND

FROM \ TO	RESIDENTIAL	CROPLAND	DESERT SHRUB	RESERVOIR
RESIDENTIAL	-	0	0	0
CROPLAND	0	-	0	1
DESERT SHRUB	0	0	-	2
RESERVOIR	0	0	0	-

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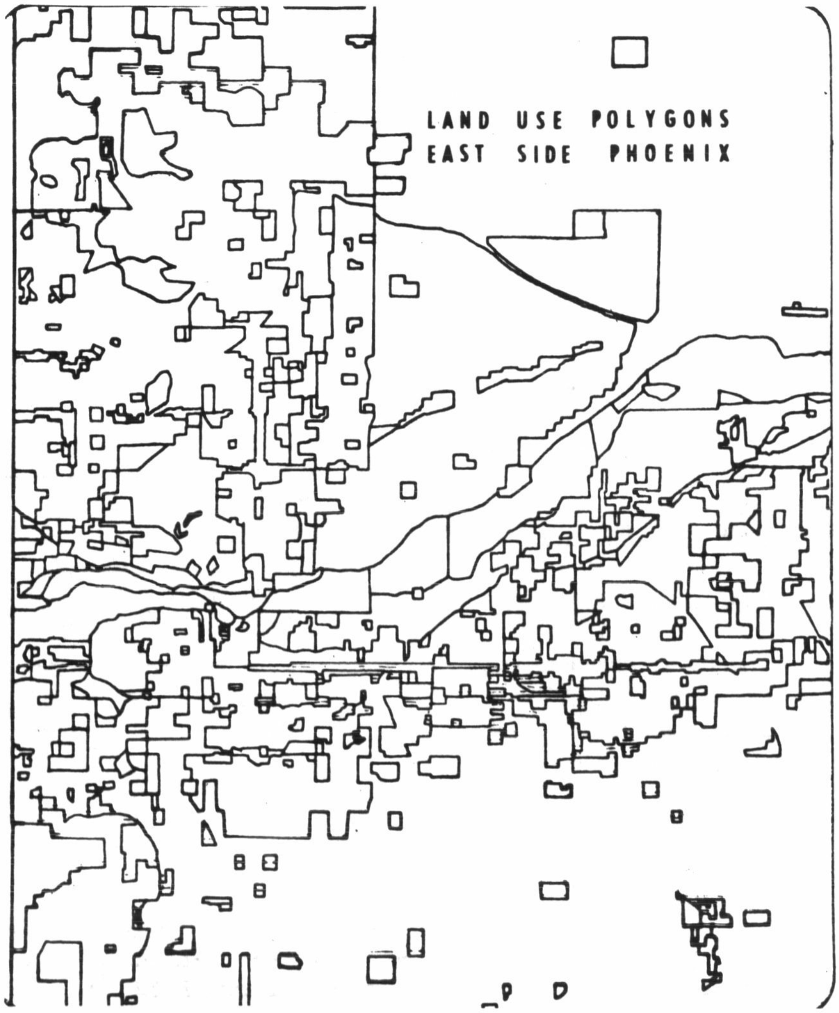
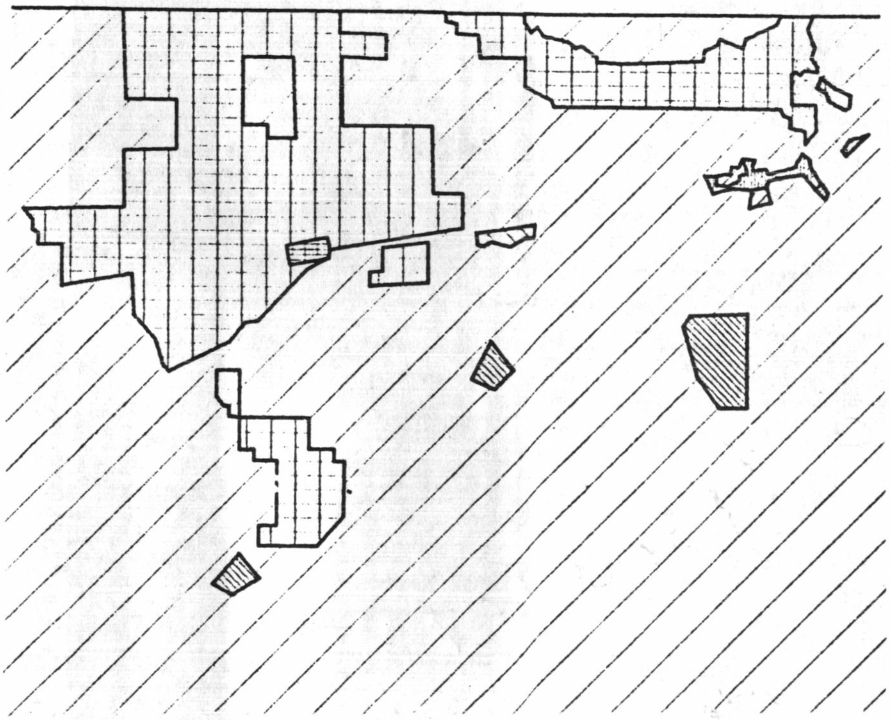
23. Changes, presented in Figure 22, broken down by land ownership class.



24. Example of an automated plot (1:120,000) of the land use map of the east half of Phoenix. The computer data bank contains the digitized record of polygon boundaries and the type of land use represented. A capability exists to fill in symbols or cells within the polygons. This is merely a test check on polygon boundary lines. Although this was made from photos, ERTS images could be used to update such a map record.



25. New technique for automated plotting of land use polygons from the computer data bank. Color symbols or cross-hatching are used to indicate land use types. This shows Gila Bend, Arizona.